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Original title on 712 A/B: Optimizing Battlefield Chemical Sensor Layouts

Revised title: _____

Presented in (input and Bold one): (**WG02**, CG___, Special Session ___, Poster, Demo, or Tutorial):

This presentation is believed to be:
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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 JUN 2007	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Optimizing Chemical Battlefield Sensor Layouts	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **ITT-AES 2560 Huntington Ave. Alexandria, VA 22303**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM202526. Military Operations Research Society Symposium (75th) Held in Annapolis, Maryland on June 12-14, 2007., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**25**	

ITT

Optimizing Chemical Battlefield Sensor Layouts

Sensor Location Optimization Tool Set (SLOTS) SPOD Study

75th MORS Symposium

14 June 2007

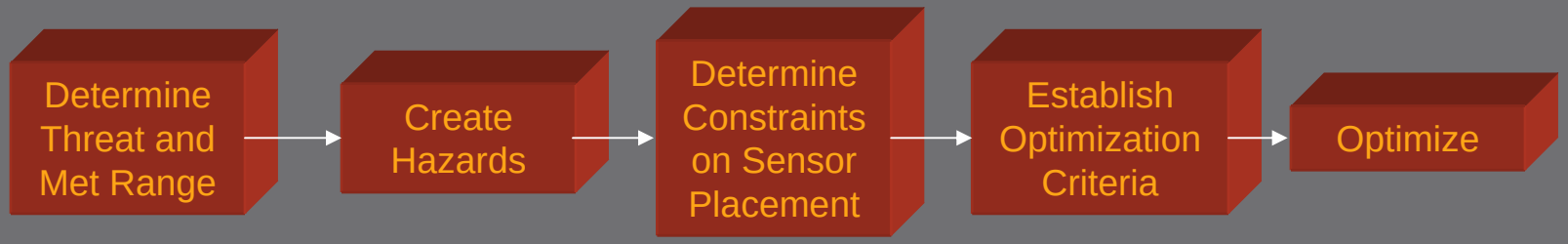
Scott Mitchell, Michael J. Smith, Javad Sedehi, Mark Henning, Samuel Freund, Stuart Edick, Julie Tittler

Engineered for life

Overview

- SLOTS Objective
- Technical Approach
- Test Case Runs
- Developing an Operational Test

Technical Approach



Train SLOTS based on a series of threats, and battlespace parameters to arrive at a generalized sensor placement scheme. Evaluate the solutions against several specific test conditions.

1. Identify parameters and appropriate ranges
   - Establish sensor kit
   - Determine met
   - Obtain Terrain Data
   - Determine threats
   - Identify high value assets
   - Determine relevant constraints
   - Define performance criteria
2. Setup and run simulations for the matrix of values determined in #1.
   - add/modify sensors representation in DAS
   - Incorporate terrain
   - Match appropriate threat sources in SCIPUFF
3. Setup SLOTS (genetic algorithm) parameters
4. Perform analysis of outcomes.

The SLOTS Architecture

Simulation Cache

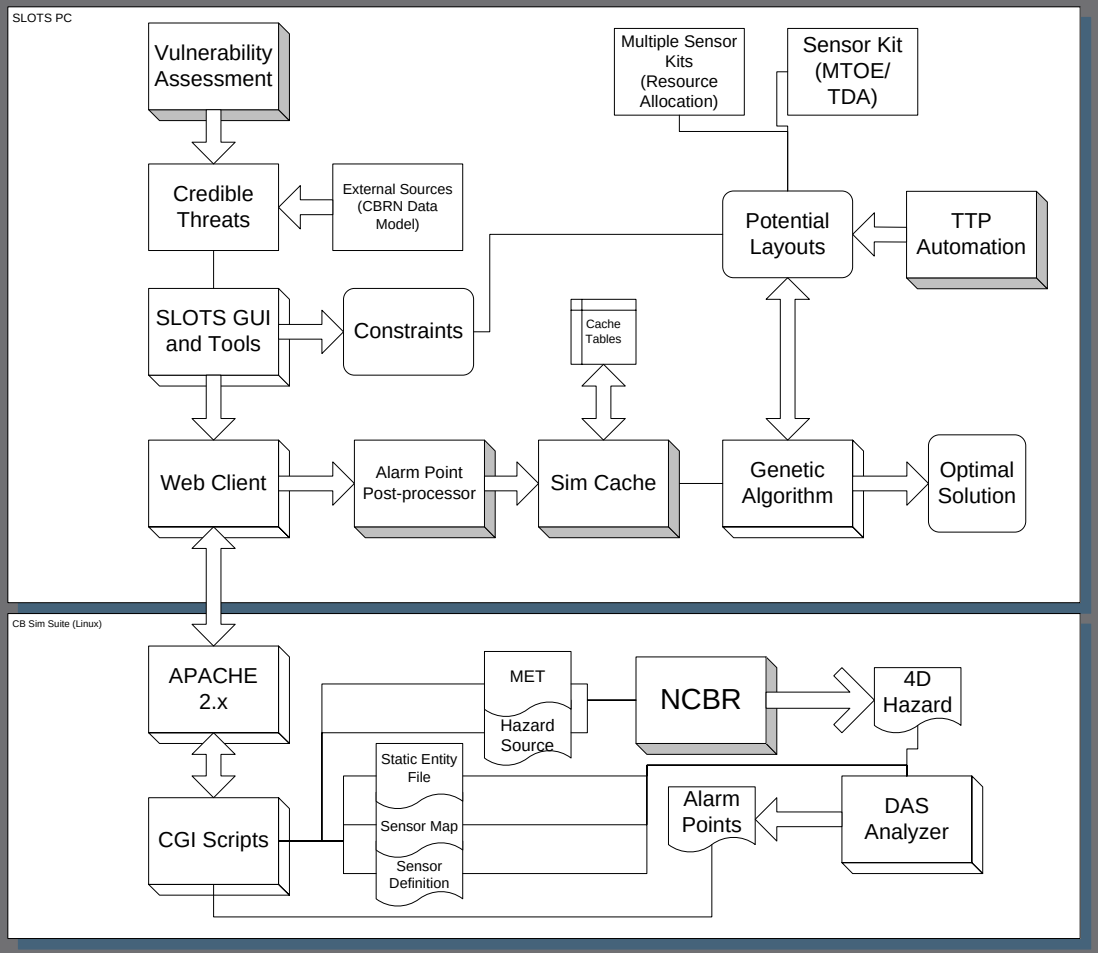
•Provide a means to employ physics based modeling and simulation to generate sensor placement environment and mitigate impact to operational timelines

Web Services Interface

•Provide an interchangeable interface to modeling and simulation tools, allowing user selectable hazard modeling applications (e.g. NCBR, JEM, etc.)

Genetic Algorithm

•Provide a global optimization solution for sensor placement.



Scoring the Results

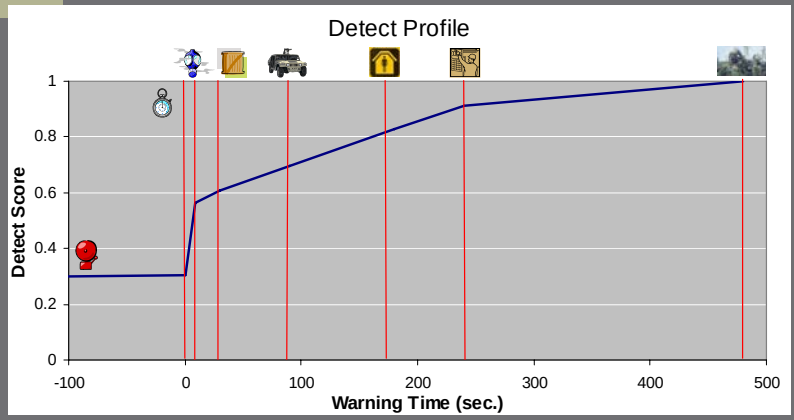
$$fitness = \sum_{threat}\left[w_{threat} \cdot \sum_{CA}\left(w_{CA} \cdot f\left(sensors, alarms_{threat}, alarms_{CA}\right)\right)\right] \cdot \text{Constraint}(sensors)$$

- Combines
  - Threats
    - Agent
    - Delivery
    - Attack placement
    - MET
  - Critical Asset
- Weighting values:
  - Attack Threat
    - Agent vulnerability
    - Agent Likelihood
    - MET Probability
  - Critical Asset importance
  - Power Law weighting

- Scoring function determines how complete preparations should be at any given time.
- Determine applicable preventative measures
  - Importance of action
  - Time required to enact

Activity	Required Time (sec)	Relative Importance
Detect	N/A	5
Zero Warning	0	1
Mask	9	6
Shelter Critical Supplies	30	1
Shelter Critical Equipment	90	2
Personnel move to shelter	180	3
Shutdown Building HVAC	240	2
Suit up	480	2

Sample User Defined Values



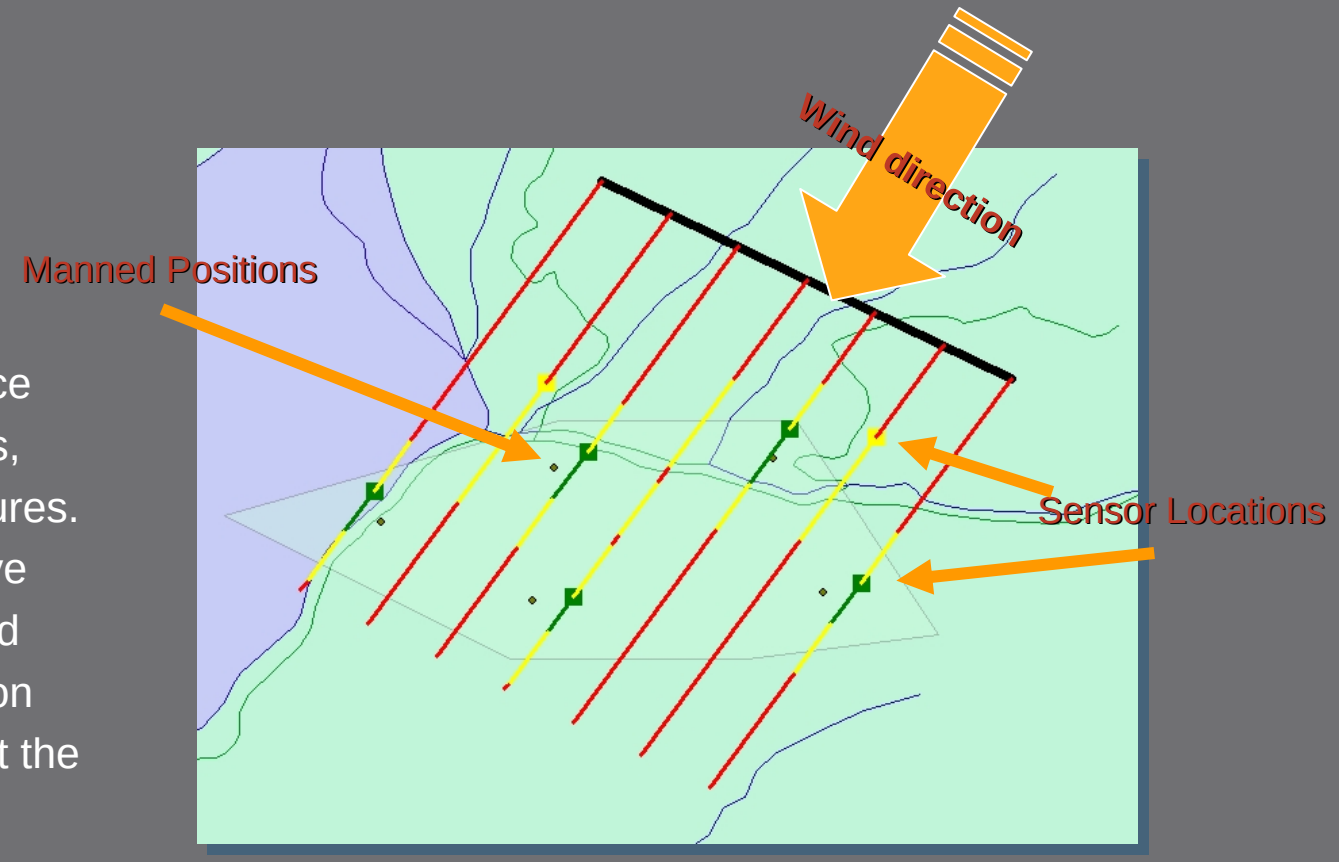
Constraints & TTP

- Hard (Fatal) Constraints
  - Areas where a sensor cannot be placed
  - Solutions edited or removed before continuing
  - Ex. Facilities, Lake, Roadways
- Soft Constraints
  - Areas where we don't want to put the sensor
  - But could if it were a good solution
  - Score penalized
  - Ex. Marshland, unprotected area
- Adjacency Constraint
  - Penalize sensors for being too close together.
  - Exponential Decay function
  - Allows sensor layout to generalize better

Site Selection
Lt. yellow – CA
Pink – Perimeter
Lt. Green – Constraint
(Max. Sensor Distance)

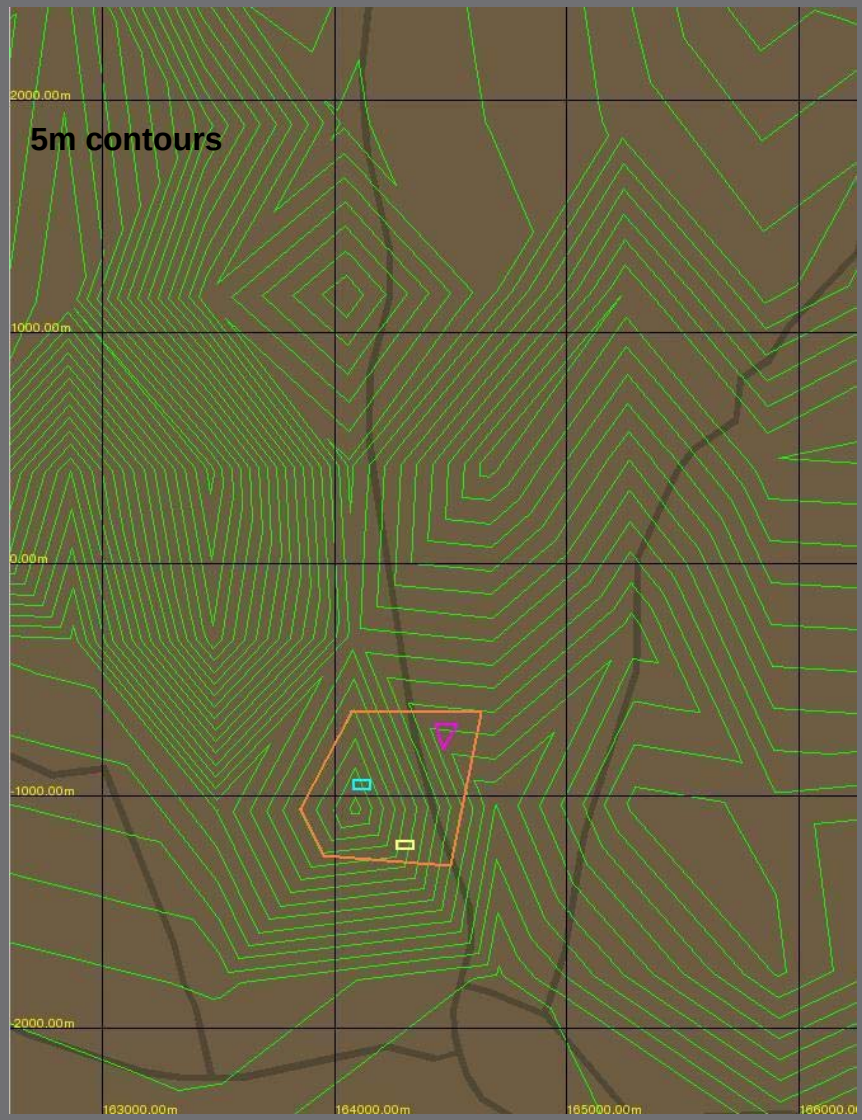
SLOTS Automated Rules-based Placement (ARP)

The ARP provides visualization of sensor positions and compliance with doctrine and tactics, techniques and procedures. Also suggests alternative positions and associated risk. It provides decision maker with quick look at the "goodness" of given a sensor placement scheme.



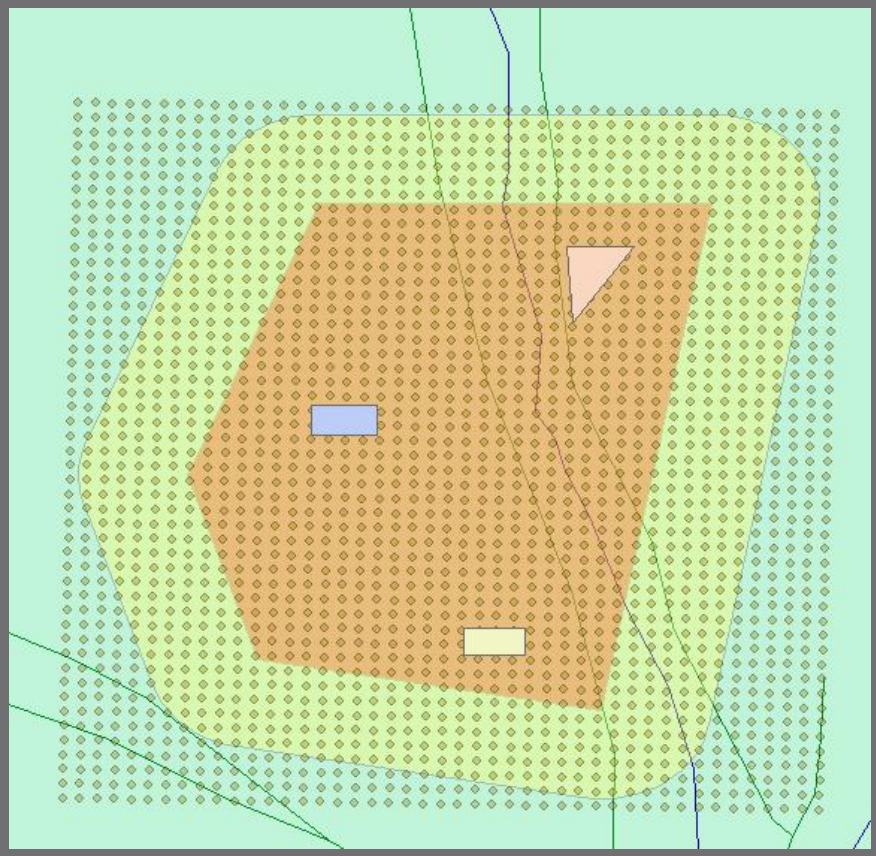
SLOTS GA Test

- Fort Hunter Liggett
- Rolling Hills
- Multiple Critical Assets
- Single Agent: GB
- Delivery
  - Scud (500kg)
  - 122mm Artillery Volley
  - 100kg Bomb
  - Line Spray from nearby roads
- Attack Placement
  - Several per Delivery & MET
- Using historic MET
  - Two wind directions (N, NNE)
  - Wind speeds at average + 1 standard deviation
  - Average Temperature
- 34 Simulations Total



Optimization

- Layout
  - Grid (25m x 25m)

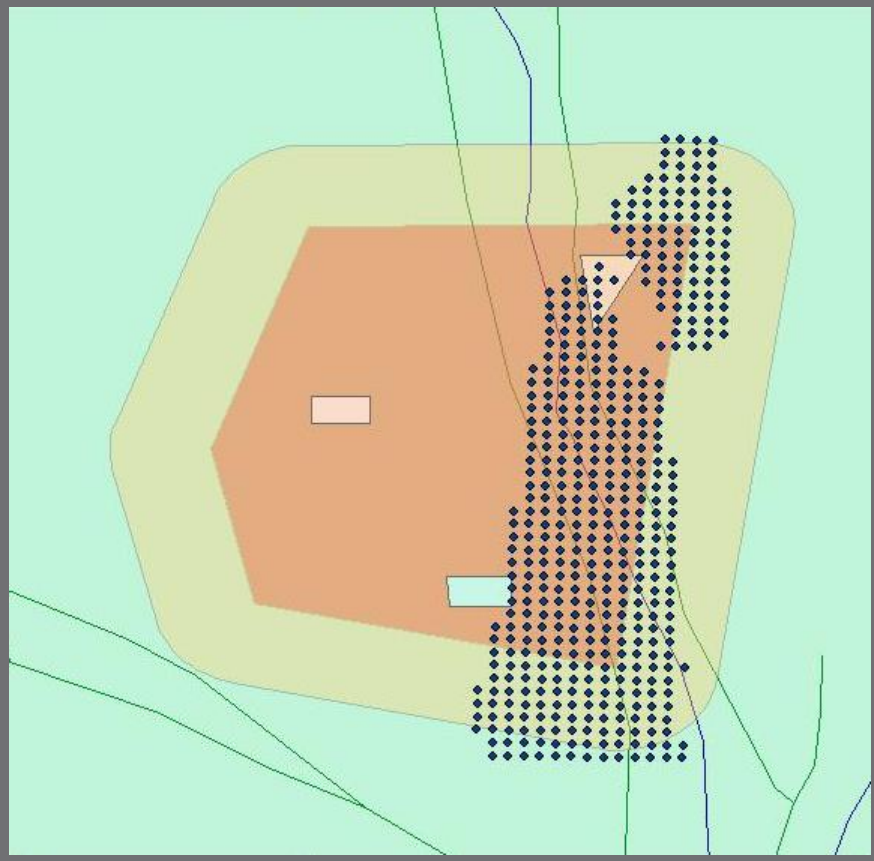


Optimization

- Layout
  - Grid (25m x 25m)
- Simulations
  - North Winds
    - Artillery @ 1100m

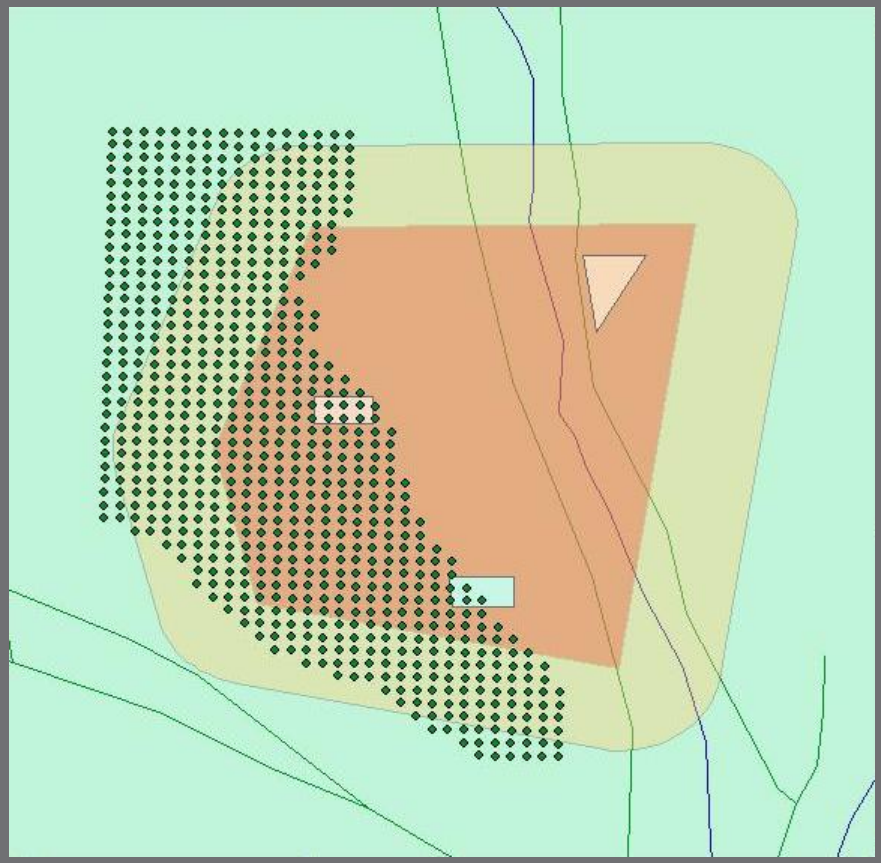
Optimization

- Layout
  - Grid (25m x 25m)
- Simulations
  - North Winds
    - Artillery @ 1100m
    - Line Spray @ 250-1500m



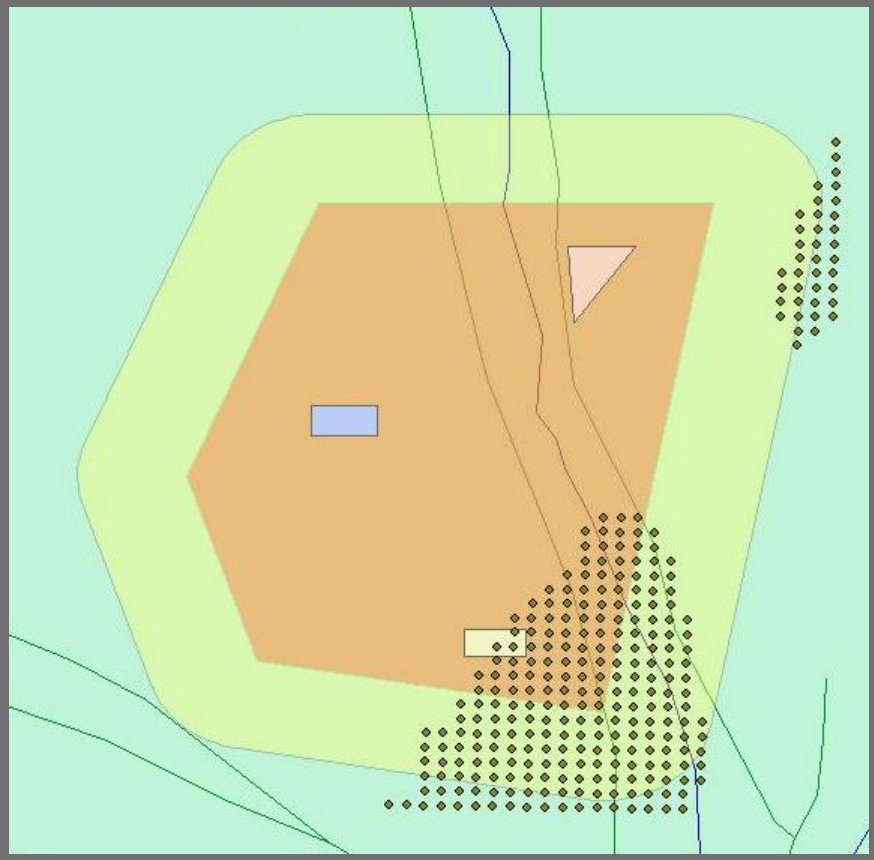
Optimization

- Layout
  - Grid (25m x 25m)
- Simulations
  - North Winds
    - Artillery @ 1100m
    - Line Spray @ 250-1500m
  - NNE Winds
    - Scud @ 2000m



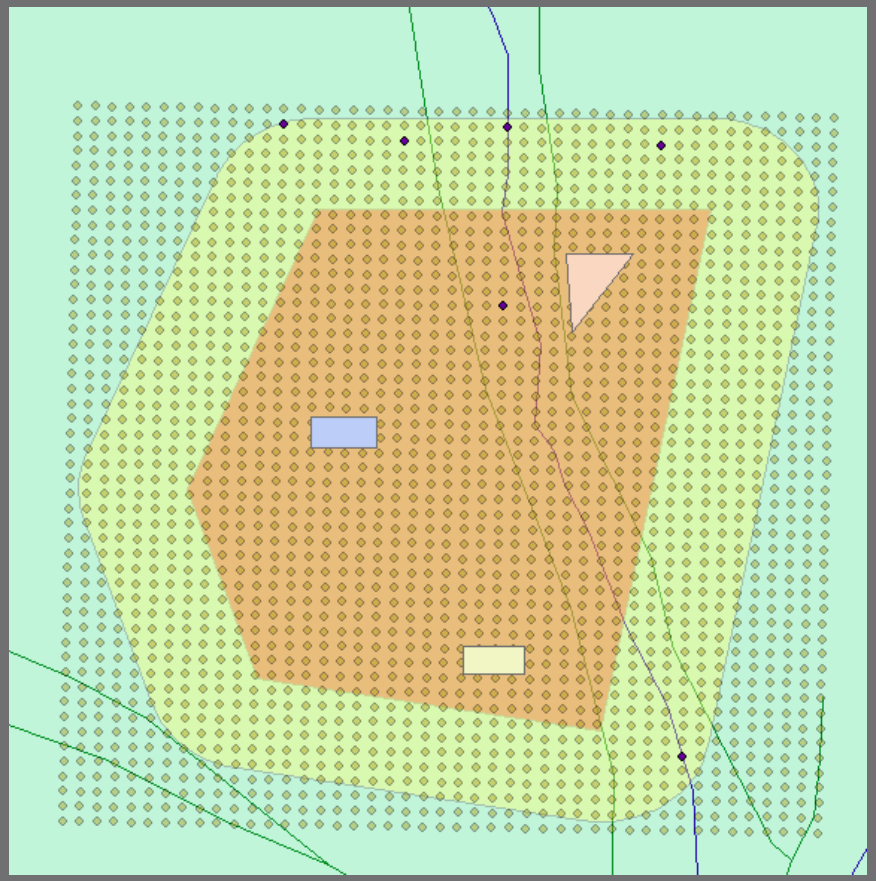
Optimization

- Layout
  - Grid (25m x 25m)
- Simulations
  - North Winds
    - Artillery @ 1100m
    - Line Spray @ 250-1500m
  - NNE Winds
    - Scud @ 2000m
    - 100kg Bomb @ 500m

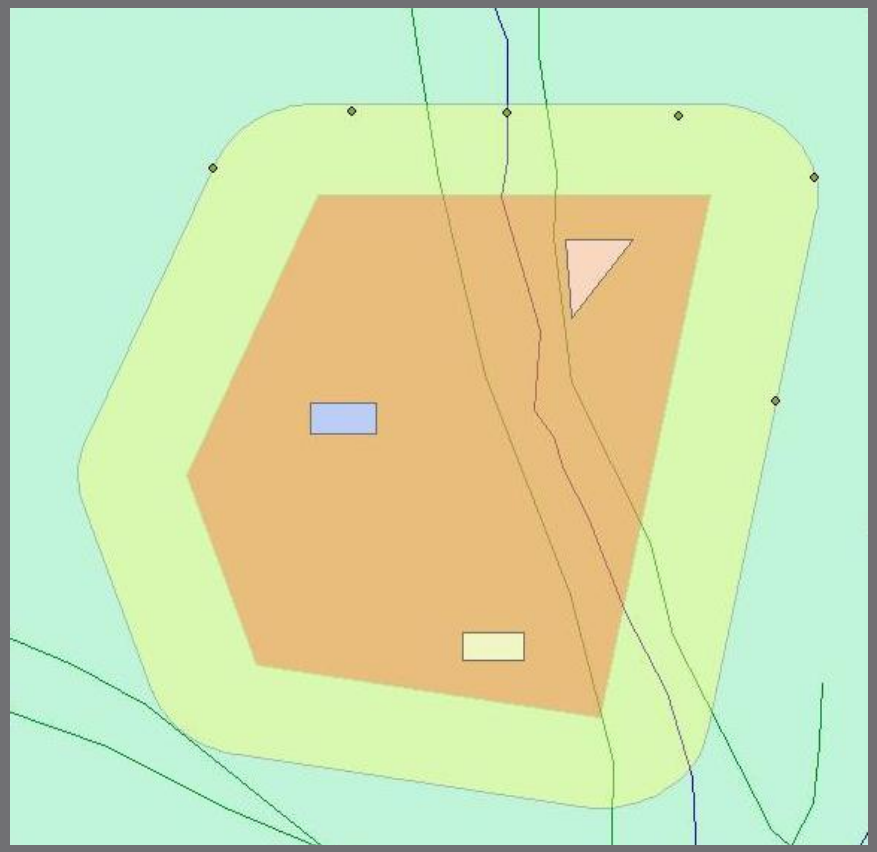


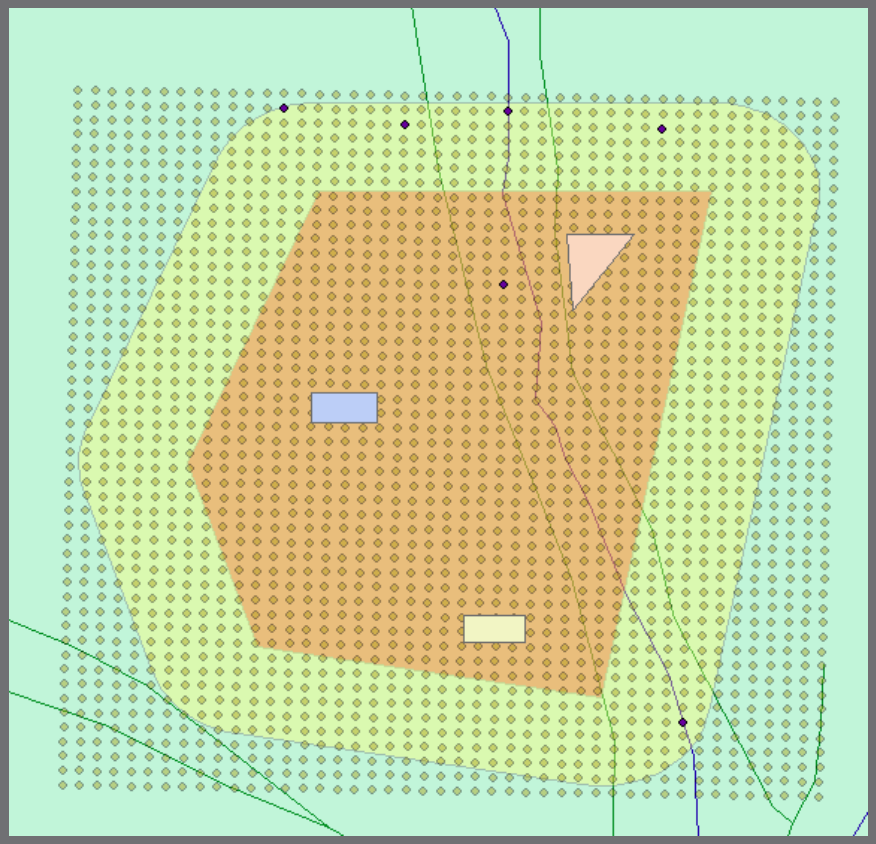
Optimization

- Layout
  - Grid (25m x 25m)
- Simulations
  - North Winds
    - Artillery @ 1100m
    - Line Spray @ 250-1500m
  - NNE Winds
    - Scud @ 2000m
    - 100kg Bomb @ 500m
- Optimal



Benchmark and Optimal





Benchmark

Score = 0.3814767

Optimal

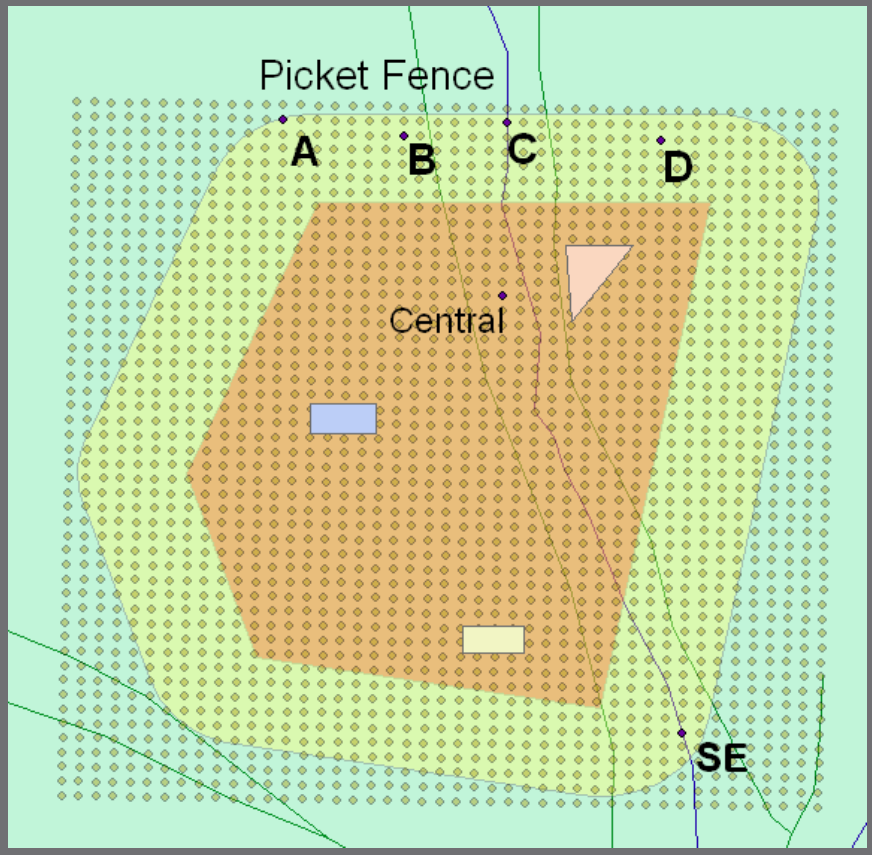
Score = 0.4668766

Why is the Optimal Better?

	Benchmark	Optimal w/ Adj Constraint
1st Sensor Detects	71	90
2nd Sensor Detects	30	54
3rd Sensor Detects	6	23
4th Sensor Detects	none	7
Undetected Asset Contaminations	17 assets on 9 attacks	0
# of Advance Warnings	58	65
Average Warning (sec)	134.2	130.2

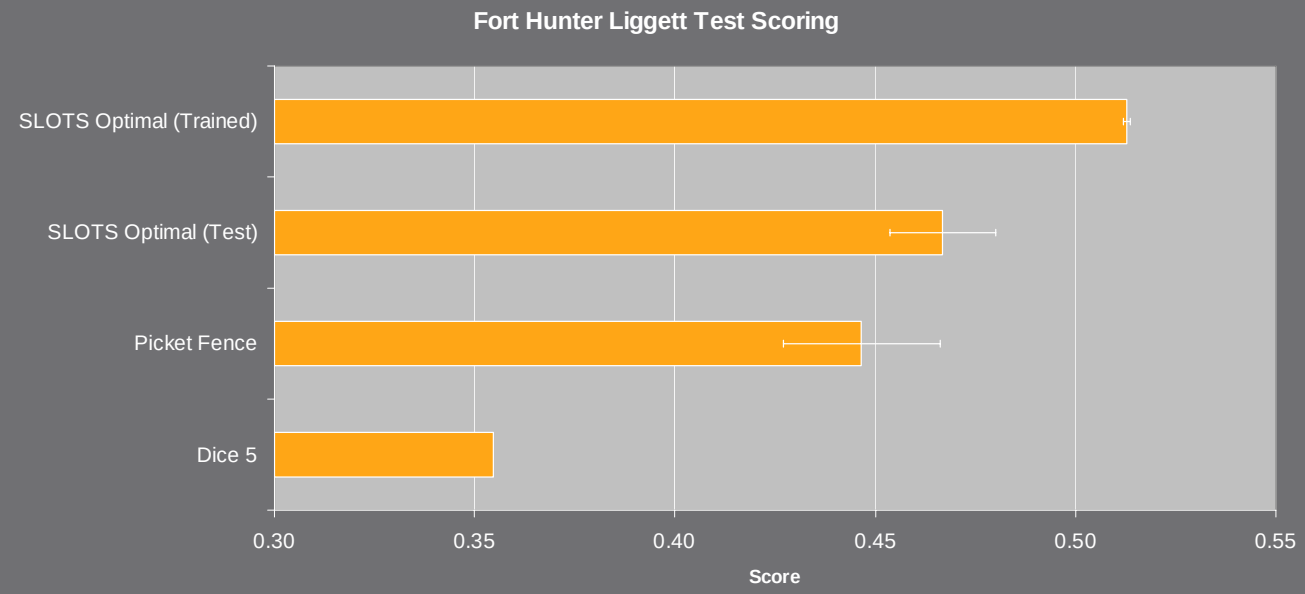
Why is that Sensor there?

- The SE sensor is critical.
  - Catches 69% of the attacks with no other detection
  - 11 first detects
  - Detects 44% of the attacks
- The Central sensor provides first detects for line spray attacks. And provides detects on 41% of attacks.
- The Picket Fence combines for 21 first detects with each sensor taking a fairly equal share.
- Picket Fence A has 19% of only detects.
- Picket Fence B detects 35% of all attacks

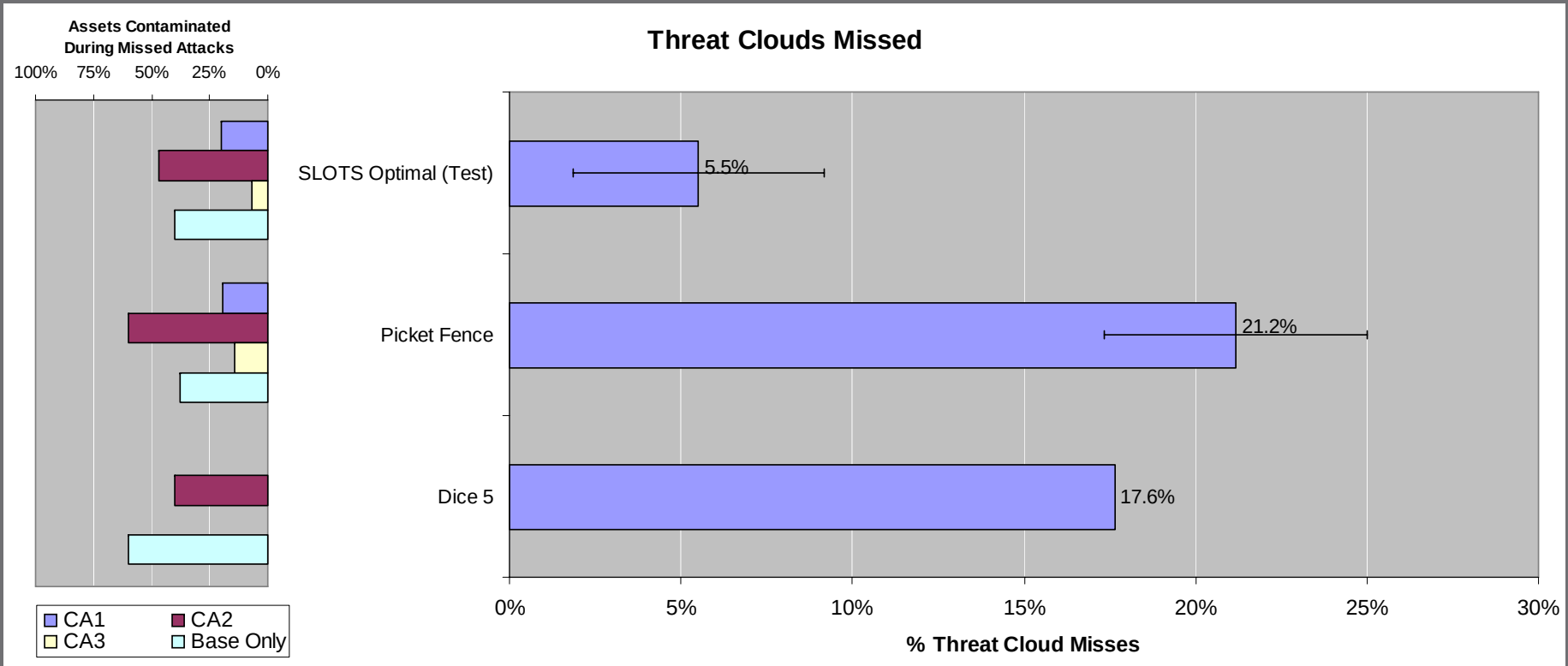


Does a SLOTS Layout *Generalize*?

- SLOTS optimal layouts are based upon a representative sample of attacks.
- How does it fare against attacks that it has not seen?
- Tested using Leave-one-out Cross-validation.
- Scores better than doctrine methods



Threat Cloud Detection



- SLOTS is able to detect threat clouds more reliably than doctrine.

SLOTS Field Trip

How will SLOTS perform in a real world scenario?

Existing sensors, operationally relevant SPOD, potentially exposed to TIC and CWA threats.

Key Input Parameters

There are several parameters which drive the fidelity of the solutions. The range of values for these determine the total number of simulations required.

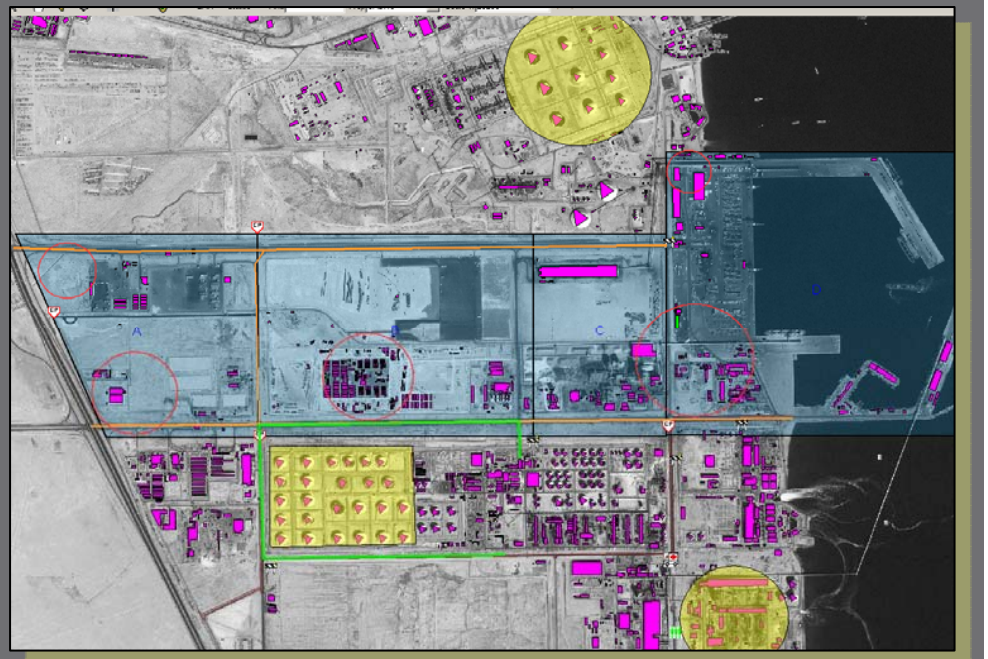
Sensor Kit

- Type (LCD 3, Multi RAE, ACADA)
- Quantity
- Mode (TIC/CWA)
- Locations
- Detection range (Threshold concentrations)

Key Input Parameters

Threat

- Agent
  - TIC (Chlorine, SO_2, Hydrogen Cyanide, H_2SO_4, Ammonia)
  - CWA (G, H, V)
- Agent Amount
  - TBD
- Source Location
  - Fixed facilities (TIC)
  - IPB determined (CWA)
- Source Type/Dissemination Method
  - Stacks (Analytical releases) for TICs
  - SCIPUFF (delivery systems) for CWAs



Key Input Parameters

Meteorology Data Sources

- Forecast
- Observations
- Historical
- Chemical Downwind Messages (CDM)

Terrain Data

- NCBR (CTDB c7l)
- SLOTS Shape file

Key Input Parameters

- High Value Assets
  - Define
  - Weight
- Constraints
  - Go
  - No Go
  - Maybe (with penalty)
- Fitness Functions
  - Understand
  - Protective Measure & Associated Time